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(54) **STRUCTURED LIGHT FOR TOUCH OR GESTURE DETECTION**

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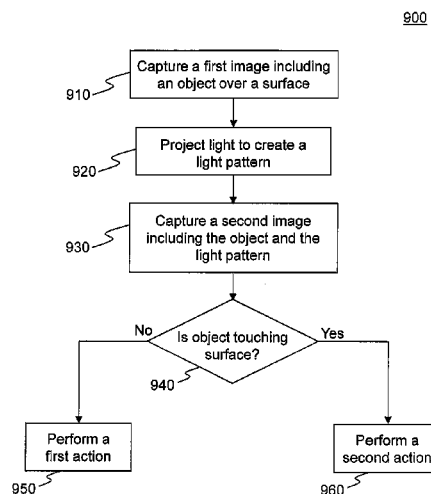Ionescu et al, A single sensor NIR depth camera for gesture control, 2014.*

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(57)   **ABSTRACT**

The subject matter disclosed herein relates to optical projection and image detection to detect touch or gesture action.

19 Claims, 6 Drawing Sheets

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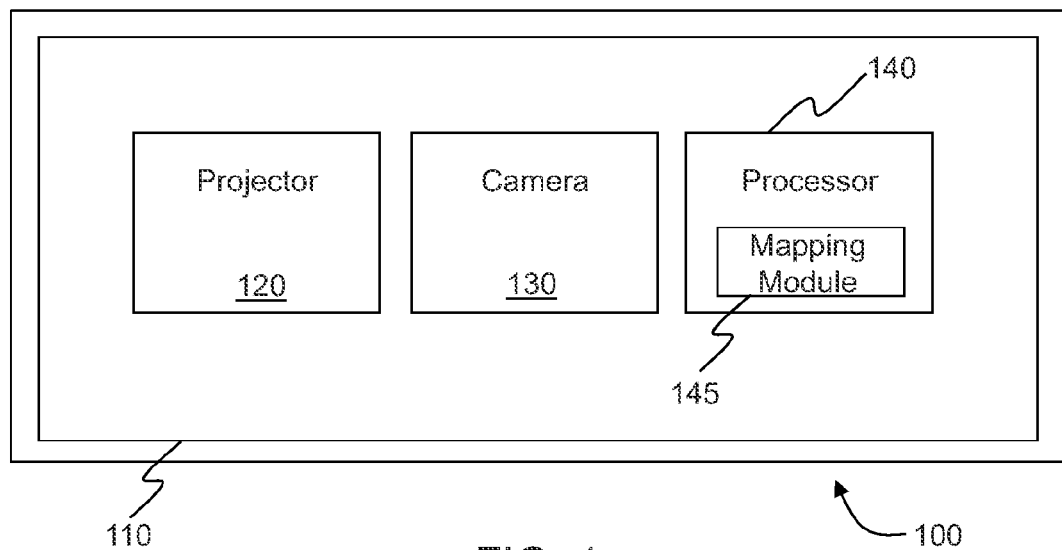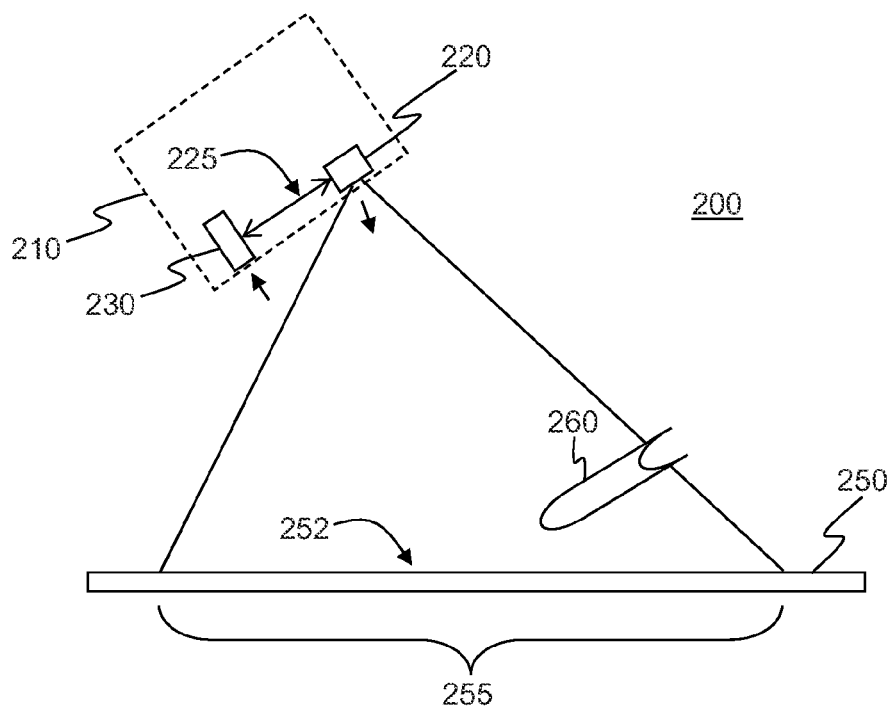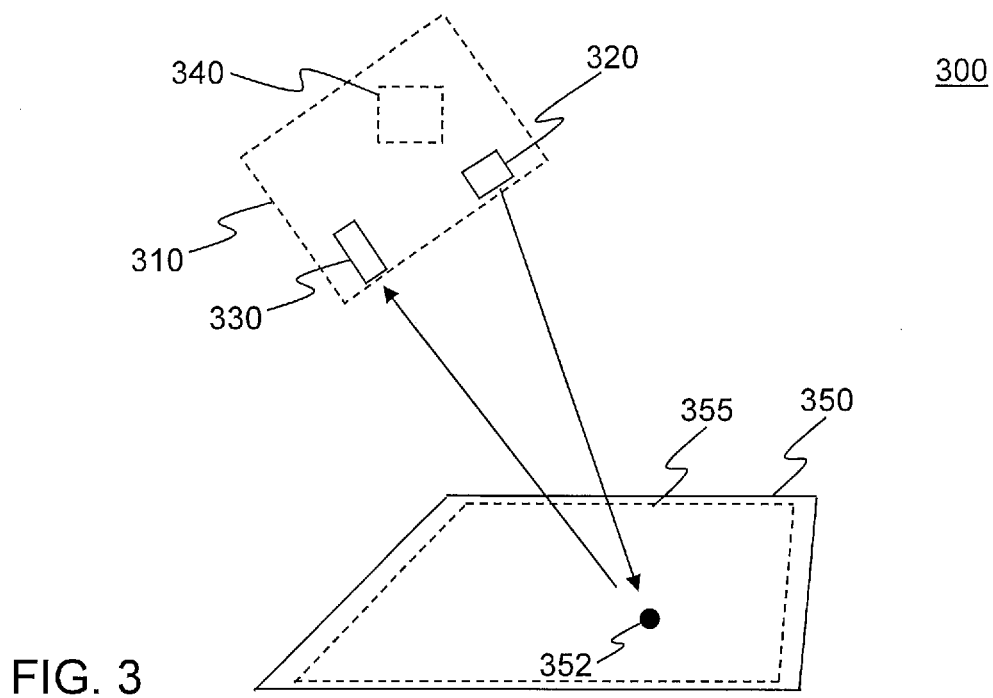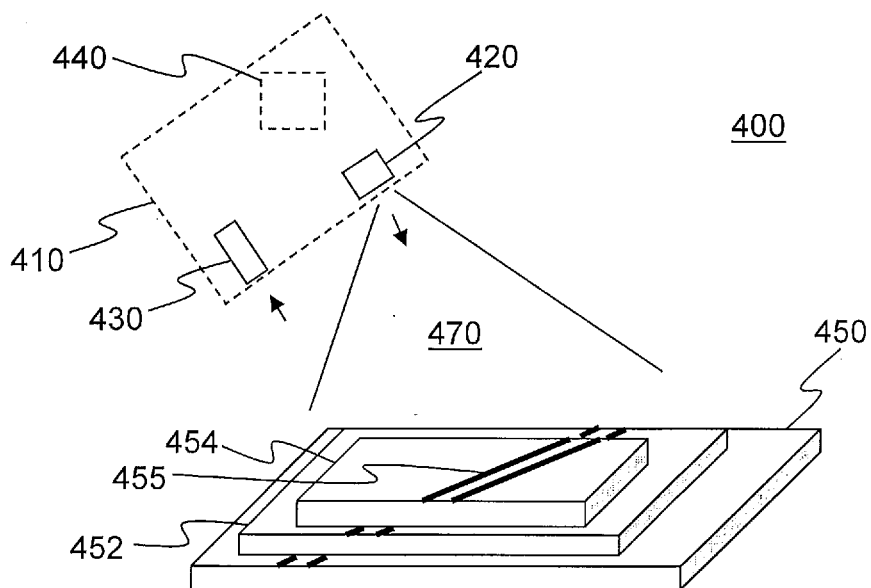
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FIG. 1

FIG. 2

300

340

320

310

330

355   350

352

FIG. 3

440

420

400

410

430

470

450

454

455

452

FIG. 4

FIG. 5

FIG. 6

710

Start

720

Create surface map

730

Detect Object

740

Does Object exist?

No

Yes

750

Generate
structured
light

760

Line broken?

No

Yes

770

Non-touch
action

780

Touch
detected

790

Re-create surface
map?

No

Yes

700

FIG. 7

FIG. 8

900

```
            ┌─────────────────────────────┐
      910   │  Capture a first image       │
            │  including an object over    │
            │  a surface                   │
            └─────────────────────────────┘
                          │
                          ▼
            ┌─────────────────────────────┐
      920   │  Project light to create a   │
            │  light pattern               │
            └─────────────────────────────┘
                          │
                          ▼
            ┌─────────────────────────────┐
            │  Capture a second image      │
      930   │  including the object and    │
            │  the light pattern           │
            └─────────────────────────────┘
                          │
                          ▼
    No        ◇ Is object touching ◇      Yes
   ◄──────────◇      surface?      ◇──────────►
              ◇                    ◇
                    940
    │                                      │
    ▼                                      ▼
┌──────────────┐                  ┌──────────────┐
│  Perform a   │                  │  Perform a   │
│  first action│                  │ second action│
└──────────────┘                  └──────────────┘
      950                               960
```
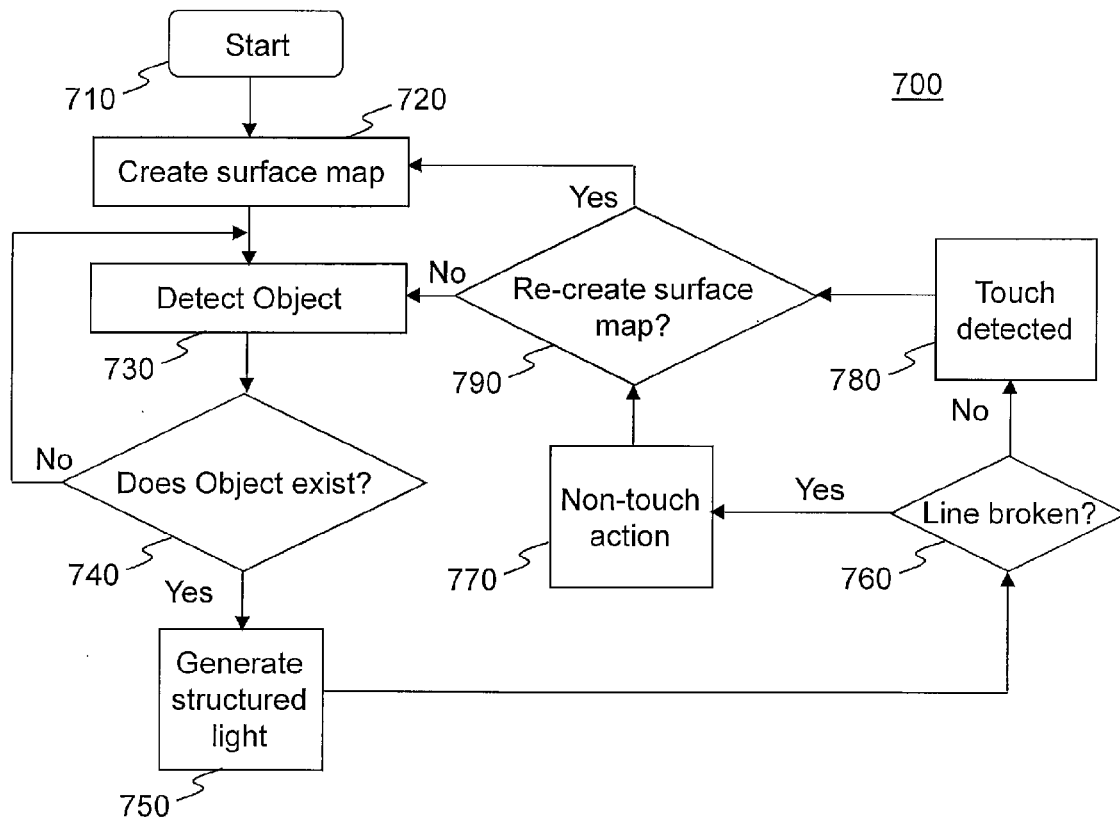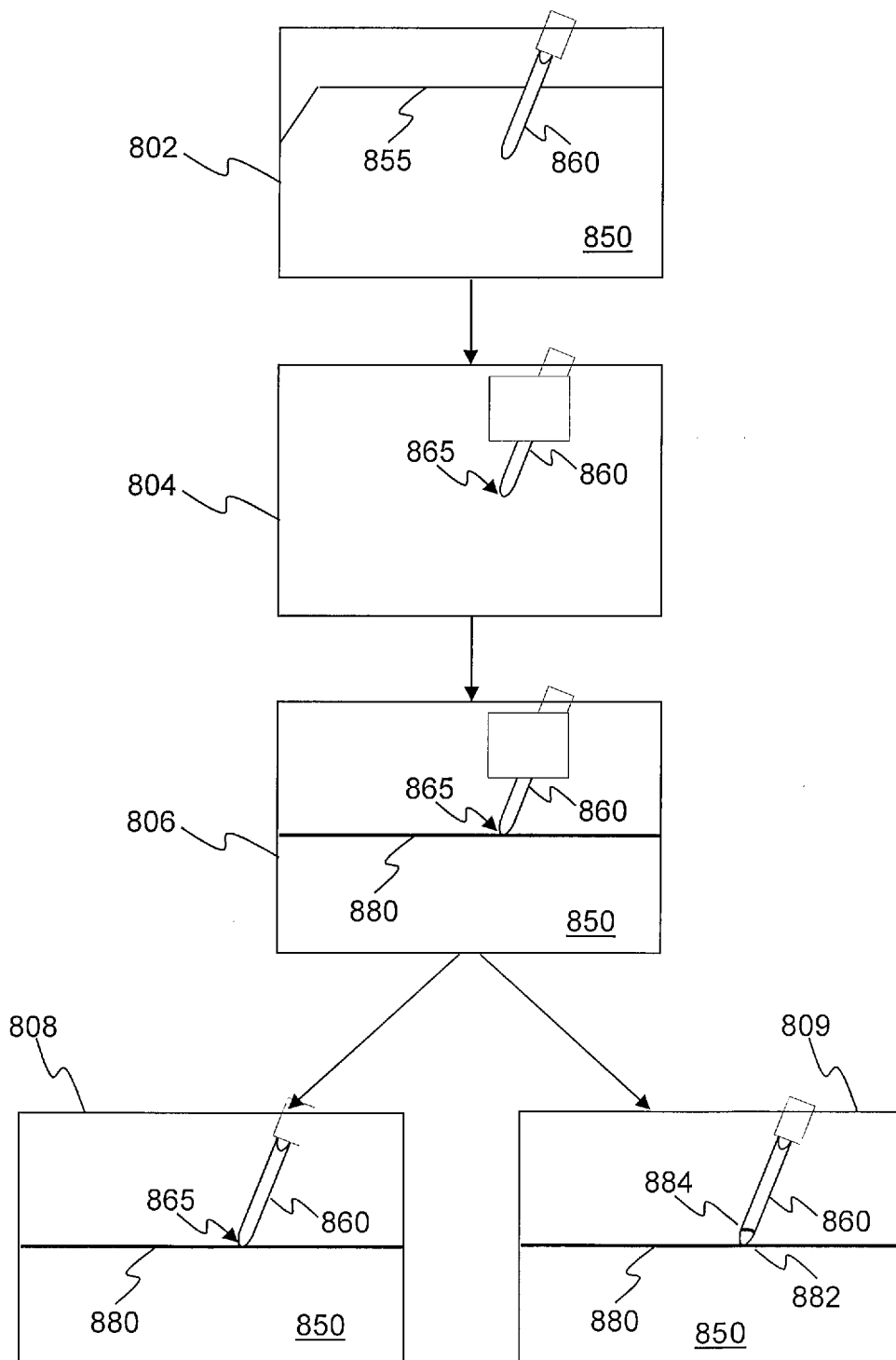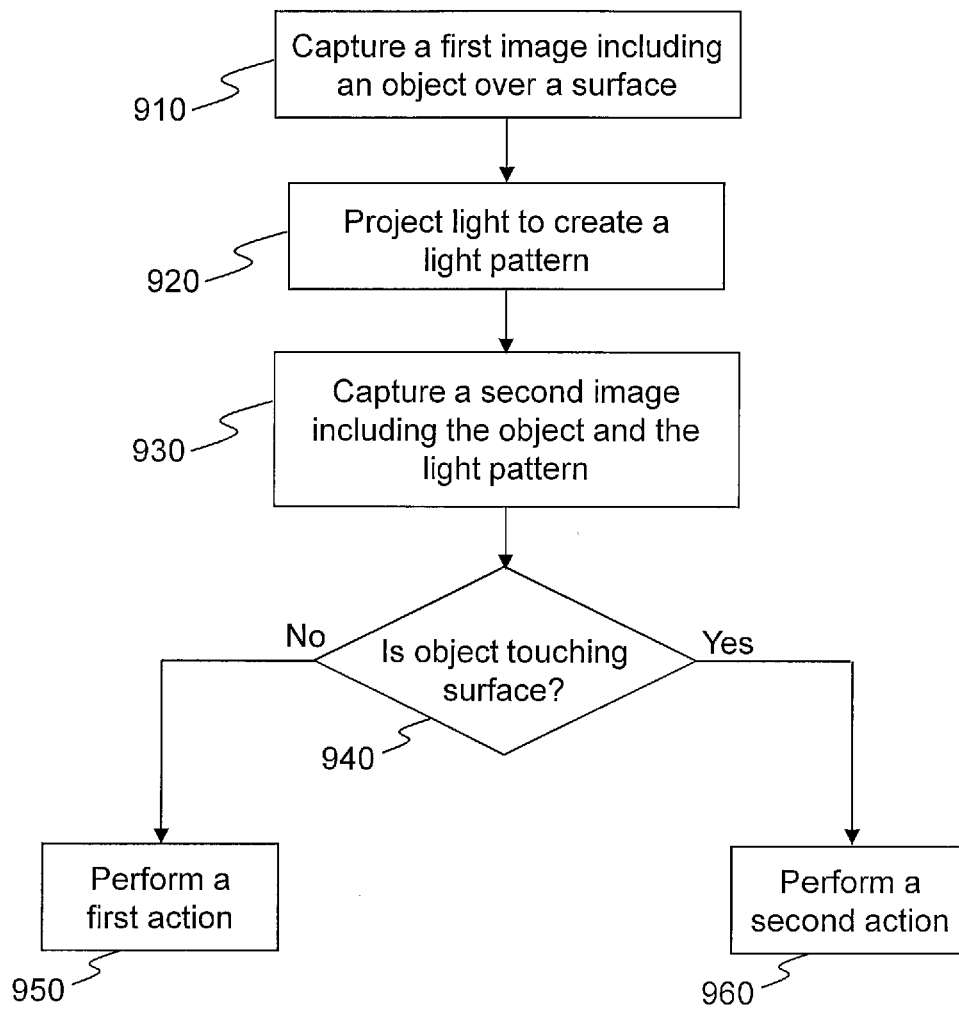
FIG. 9

STRUCTURED LIGHT FOR TOUCH OR GESTURE DETECTION

FIELD

The subject matter disclosed herein relates to optical projection and image detection to detect touch or gesture action.

BACKGROUND

It may be desirable to use virtual input devices to enter commands, data, or other information into electronic systems, such as a cellular phone, smart phone, personal data assistant (PDA), laptop computer, and so on. Such electronic devices implemented in relatively small sizes may have relatively small touch screens or mini-keyboards. Entering commands or data may be time consuming or error-prone. For example, cellular telephones, PDAs, or smart phones may allow e-mail communications, but entering messages using a small telephone touch pad may be difficult. For example, a PDA or a smart phone may have much of the functionality of a computer but may suffer from a tiny or non-existent keyboard.

BRIEF DESCRIPTION OF THE DRAWINGS

Non-limiting and non-exhaustive embodiments will be described with reference to the following objects, wherein like reference numerals refer to like parts throughout the various objects unless otherwise specified.

FIG. **1** is a schematic block diagram of an electronic device, according to an embodiment.

FIG. **2** is a schematic diagram of a projection-detection system, a touch object, and a surface, according to another embodiment.

FIG. **3** is a schematic diagram of a projection-detection system and a surface, according to an embodiment.

FIG. **4** is a schematic diagram of a projection-detection system and a surface, according to another embodiment.

FIG. **5** is a schematic diagram of a projection-detection system, a touch object, and a surface, according to another embodiment.

FIG. **6** is a schematic diagram of a projection-detection system, a touch object, and a surface, according to yet another embodiment.

FIG. **7** is a flow diagram of a process to detect whether an object touches a surface, according to an embodiment.

FIG. **8** is an image flow diagram of a process to detect whether an object touches a surface, according to an embodiment.

FIG. **9** is a flow diagram of a process to detect whether an object touches a surface, according to another embodiment.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth to provide a thorough understanding of claimed subject matter. However, it will be understood by those skilled in the art that claimed subject matter may be practiced without these specific details. In other instances, methods, apparatuses, or systems that would be known by one of ordinary skill have not been described in detail so as not to obscure claimed subject matter.

Reference throughout this specification to "one embodiment" or "an embodiment" may mean that a particular feature, structure, or characteristic described in connection with a particular embodiment may be included in at least one

embodiment of claimed subject matter. Thus, appearances of the phrase "in one embodiment" or "an embodiment" in various places throughout this specification are not necessarily intended to refer to the same embodiment or to any one particular embodiment described. Furthermore, it is to be understood that particular features, structures, or characteristics described may be combined in various ways in one or more embodiments. In general, of course, these and other issues may vary with the particular context of usage. Therefore, the particular context of the description or the usage of terms may provide helpful guidance regarding inferences to be drawn for that context.

Embodiments described herein include an electronic device that may support one or more writing pad functions such as, for example, detecting touch action during entry of commands, data, or other information into the electronic device. For example, a user may enter a command or data into an electronic device via a virtual keyboard displayed on a surface. A user may enter a command or data by touching an image of a key, for example, on a surface. In contrast, a command or data need not be entered into an electronic device if a user merely holds a finger or stylus above such an image of a key so as to not touch the surface. Accordingly, detecting touch action may allow an electronic device to determine whether a user intends to enter a command or data. Moreover, detecting touch action may allow an electronic device to recognize particular hand or finger gestures corresponding to particular commands, for example. Of course, claimed subject matter is not limited to any such details of user interaction with a virtual keyboard.

An electronic device may comprise a portable electronic device, such as a smart phone, cellular phone, PDA, computer notebook or laptop, and so on. For example, an electronic device may determine if a user's fingers or stylus contact (e.g., touch) a virtual keyboard displayed on a surface. In such a case, an electronic device may further determine which fingers of a user contact which virtual keys, or may determine or identify gestures performed by the user's hand or fingers, for example. Terms "finger", "fingers", and "stylus" are used interchangeably herein. Moreover, "touch object" or "object" may be used in lieu of these terms.

A virtual keyboard, for example, may offer a user an alternative to entering commands or data into a portable electronic device (e.g., smart phone, and so on) using a relatively small touch screen or mini-keyboard. A larger size of a virtual keyboard may be convenient for a user entering e-mail or text into a smart phone or cellular telephone, for example.

In one implementation, a virtual keyboard may comprise a surface (e.g., a sheet of paper, a desktop, and so on) that includes a projected image of a keyboard or other input device or interface. A virtual keyboard or other input device or interface may comprise a work surface that need not include sensors or mechanical or electronic components, for example. A surface displaying a virtual keyboard need not actually perform a process of entering commands or data into an electronic device. Instead, an interaction between a touch object (e.g., a user's fingers or stylus) and portions of a work surface, whereon images of keys exist, may be detected by an electronic device to enter information into the electronic device.

In some embodiments, a method of determining whether an object touches a surface may comprise capturing a first image that includes an image of the object proximate to the surface. The term "proximate" means that an object may be touching a surface or the object may not be touching the surface but may be hovering above the surface by some distance of separation. Light may be projected to create a light

3

pattern on the surface. Such a projected light pattern may be determined based, at least in part, on the first image and a surface map of the surface. Embodiments of techniques to develop a surface map of a surface are discussed below. In one implementation, a projected light pattern may comprise a straight line on a flat surface.

A method of determining whether the object touches the surface may further comprise capturing a second image that includes an image of the light pattern superimposed on the object. In one implementation, the object may be determined not to be touching the surface if the light pattern in the second image includes one or more discontinuities, as explained below. On the other hand, the object may be determined to be touching the surface if the light pattern in the second image does not include a discontinuity.

In one embodiment, a mapping relationship between a surface map of a surface and a projector-camera system, as described above, may be determined. Such a mapping relationship may be used to translate among locations on a surface as seen by a camera and locations on the surface as seen from a location of a projector, as explained below.

In some embodiments, a method of determining whether an object touches a surface may comprise detecting a location of a tip of the object based, at least in part, on a first image, as described above, and projecting light to create a light pattern based, at least in part, on the location of the tip of the object and a surface map of the surface.

In other embodiments, a device, apparatus, or system for performing a method of determining whether an object touches a surface may comprise a mapping module to determine a mapping relationship between an image projected on a surface and a captured image of the surface. A projector may be used to produce such a projection image. The projector may also produce a light pattern to project on the surface. In one implementation, a projector may comprise a red-green-blue (RGB) projector. In another implementation, a projector may comprise a projector capable of projecting infrared (IR) light, such as an RGB-IR projector, for example. Accordingly, in a particular implementation, a light pattern produced by a projector may comprise IR light, while a projection image produced by the projector may comprise visible light.

The device, apparatus, or system for determining whether the object touches the surface may further comprise a camera to capture the image of the surface, an image of the light pattern, and an image of the object. An optical axis of the camera may be arranged at a substantially non-orthogonal angle with respect to the surface, for example. In one implementation, a camera may comprise a visible-IR camera, capable of capturing images produced by an RGB-IR projector, for example.

Such a device, apparatus, or system may further comprise a processor to determine whether the object touches the surface based, at least in part, on the image of the light pattern. For example, a processor may determine that an object does not touch a surface if an image of a light pattern includes one or more discontinuities. On the other hand, a processor may determine that an object touches a surface if an image of a light pattern does not include a discontinuity, as described below.

In one implementation, a device, apparatus, or system for determining, among other things, whether an object touches a surface may be incorporated in a mobile device. For example, a smart phone, PDA, portable computer (e.g., laptop or notebook computer), and so on may comprise a mapping module, a projector, a camera, or a processor to determine whether an

4

object touches a surface. Of course, such mobile devices are merely examples, and claimed subject matter is not limited in this respect.

In some embodiments, particular techniques for determining, among other things, whether an object touches a surface may provide a number of benefits. For example, a device, apparatus, or system for performing such techniques may include a camera and a projector and need not include an additional light sensor or an additional light source. Thus, a portable electronic device including a projector module and a camera module may perform a number of processes, such as those described in example embodiments herein. A device, apparatus, or system for performing such techniques may also be able to create a surface map of a surface on which a virtual keyboard, for example, may be displayed. Moreover, such a surface need not be flat, as explained below. Of course, such benefits are merely examples, and claimed subject matter is not so limited. Further, such benefits are merely a few of a number of other benefits.

FIG. 1 is a schematic block diagram of an electronic device 100, according to an embodiment. For example, electronic device 100 may comprise a portable device such as a smart phone, laptop computer, or PDA, just to name a few examples. Electronic device 100 may include a sensing device 110 to sense, detect, or determine any of a number of actions performed by a user of electronic device 100. For example, in one implementation, sensing device 110 may determine whether a user's finger or stylus touches a surface comprising a virtual keyboard. In such a case, device 110 may further determine which fingers of a user contact which virtual keys. In another implementation, sensing device 110 may determine or identify a gesture performed by a user's hand or finger over a surface comprising a virtual keyboard, for example.

Sensing device 110 may include a projector 120 for producing a projection image and a light pattern on a surface. In one implementation, projector 120 may comprise an RGB projector. In another implementation, projector 120 may comprise an RGB-IR projector, for example. Accordingly, in a particular implementation, a light pattern produced by projector 120 may comprise IR light, while a projection image produced by the projector may comprise visible light.

Sensing device 110 may also include a camera 130 to capture an image of the surface, an image of the light pattern, and an image of a touch object (e.g., an object, such as a finger or stylus, which may touch the surface). In one implementation, camera 130 may comprise a visible-IR camera, capable of capturing images produced by projector 120, for example.

A mapping module 145 may determine a mapping relationship between a projection image on the surface and a captured image of the surface, as described in detail below. A processor 140, which may include mapping module 145, may determine whether an object touches a surface based, at least in part, on an image of a light pattern.

For example, processor 140 may determine that an object does not touch a surface if an image of a light pattern includes one or more discontinuities. On the other hand, processor 140 may determine that an object touches a surface if an image of a light pattern does not include a discontinuity.

FIG. 2 is a schematic diagram of a projection-detection system 210, a touch object 260, and a surface 250, according to an embodiment 200. For example, system 210 may comprise a portable device such as a smart phone, laptop computer, or PDA, just to name a few examples. System 210 may include a projector 220 for producing a projection image 252 on surface 250. Image 252 may comprise a virtual keyboard displayed on surface 250, which may comprise a sheet of

paper, a desktop, or a notebook, just to name a few examples. Image **252** may cover an area **255**, indicated in FIG. **2**.

A camera **230** may capture image **252** on surface **250** and an image of touch object **260**, which may comprise a finger or stylus of a user, for example. Camera **230** and projector **220** may be disposed in system **210** so as to be separated by a distance **225**. Also, an optical axis of camera **230** or projector **220** may be substantially non-orthogonal with respect to surface **250**. Accordingly, such a separation may prevent the projector and the camera from sharing the same optical path. For example, image **252** may be projected onto surface **250** by projector **220** at a particular angle with respect to surface **250**. On the other hand, image **252** may be captured by camera **230** at a different angle with respect to surface **250**. Accordingly, image **252** may appear differently as viewed from (a location of) projector **220** and camera **230**. Such a difference may be used in a method to determine whether touch object **260** touches surface **250**, as explained below.

FIG. **3** is a schematic diagram of a projection-detection system **310** and a surface **350**, according to an embodiment. For example, system **310** may comprise a portable device such as a smart phone, laptop computer, or PDA, just to name a few examples. System **310** may include a projector **320** for producing a projection image **355** on surface **350**. Image **355** may comprise a virtual keyboard or other image displayed on surface **350**. In particular, image **355** may include an image portion **352**. A camera **330** may be used to capture image **355** including portion **352**. As indicated above, camera **330** and projector **320** may be separated by a distance that may prevent the projector and the camera from sharing the same optical path. Accordingly, image **355** may appear differently as viewed from (a location of) projector **320** and camera **330**. In one embodiment, a transform function, for example, may be used to map portions, such as **352**, of image **355** relative to projector **320** to image **355** relative to camera **330**. For example, a transform function may be determined by the following relation:

$$\vec{X}_i' = H\vec{X}_i \qquad\qquad \text{Equation 1}$$

Here, $\vec{X}_i'$ may represent point i in position coordinates of image **355** with respect to projector **320**, and $\vec{X}_i$ may represent the same point position coordinates of image **355** with respect to camera **330**. Also, H may represent transformation variables, which may be based, at least in part, on a distance between projector **320** and camera **330**. Such transformation variables may also be based, at least in part, on angles of optical axes of projector **320** and camera **330** with respect to surface **350**, though claimed subject matter is not so limited. System **310** may include a processor **340** (which may include a mapping module, such as **145**, shown in FIG. **1**, for example) to execute one or more applications that may use Equation 1 to determine mapping between image **355** relative to projector **320** and image **355** relative to camera **330**.

FIG. **4** is a schematic diagram of a projection-detection system **410** and a non-flat surface **450**, according to an embodiment **400**. For example, system **410** may comprise a portable device such as a smart phone, laptop computer, or PDA, just to name a few examples. System **410** may include a projector **420** for producing a projection image on surface **450**. Such an image may comprise a virtual keyboard or other image displayed on surface **350**. Projector **420** may also produce a light pattern **455** on surface **450**. As explained below, such a light pattern may be used to determine a surface geometric profile. Moreover, light pattern **455** may be used to scan a projection surface. After a scanning result has been acquired by camera **430**, the surface geometry property may

be determined and a corresponding transformation from camera space to projection space according to each point on the non-flat surface may be determined by one or more applications executed by processor **440**, such as for Equation 1, for example.

Surface **450**, in an embodiment, need not be flat. Here, surface **450** may include portions **452** and **454** that extend above other portions of surface **450**. Light pattern **455** may be used by one or more applications executed by processor **440** to determine a shape or profile of surface **450**. For example, light pattern **455** may be included in an image captured by camera **430**. Light pattern **455** included in such an image may be different from a light pattern projected by projector **420**. As mentioned above, this may be because camera **330** and projector **320** may be separated by a substantial distance (e.g., several millimeters to more than several centimeters). For example, projector **420** may project a light field **470** to produce a light pattern comprising multiple parallel straight lines. However, an image of a light pattern, as captured by camera **430**, may appear different from the light pattern projected by projector **420**. Such a difference may depend, at least in part, on a surface profile of surface **450**.

Thus, straight lines of a light pattern projected by projector **420** may also be straight in an image of the light pattern captured by camera **430** if surface **450** is flat. However, such projected straight lines, as captured in an image taken by camera **430**, may include discontinuities corresponding to steps in a surface profile of surface **450**. Such steps in surface profile, for example, may occur, among other locations, between surface portions **452** and **454**. In another example, such projected straight lines, as captured in an image taken by camera **430**, may include curved lines corresponding to a curved surface profile of surface **450** (though such a curved surface profile is not shown).

FIGS. **5** and **6** are schematic diagrams of a projection-detection system **510**, a touch object **560**, and a surface **550**, according to some embodiments. System **510** may include a projector **520** and a camera **530**, for example. In FIG. **5**, touch object **560** may be touching surface **550**. In FIG. **6**, touch object **560** may not be touching surface **550**. As mentioned above, projector **520** and camera **530** being separated by some distance **525** may give rise to an image or pattern projected on surface **550** being different as viewed from projector **520** and camera **530**. Manifestations of such a difference are now explained with respect to embodiments of FIGS. **5** and **6**, for example.

In FIG. **5**, camera **530** may capture an image of surface **550** and object **560**, including tip **565**. Arrow **535** may indicate an angle or direction at which camera **530** "sees" tip **565**. An application executed by a processor **540** may determine that tip **565** is located at a point A on surface **550**, for example. Accordingly, subsequent to determining a location of tip **565** (e.g., at point A), projector **520** may project an image of a small spot (or line, as in embodiments described for FIGS. **7-9**, below) along arrow **525** to be located at point A. In this case, the projected spot and the tip **565** of object **560** may be co-located at point A. This may not be the case, however, if object **560** is not touching surface **550**, as follows.

In FIG. **6**, camera **530** may capture an image of surface **550** and object **560**, including tip **565**. Arrow **635** may indicate an angle or direction at which camera **530** "sees" tip **565**. An application executed by processor **540** may determine that tip **565** is located at a point A' on surface **550**, for example. In this case, point A' may not be co-located with tip **565** because object **560** (and tip **565**) is elevated above surface **550**. Accordingly, subsequent to determining a location of tip **565** (e.g., at point A'), projector **520** may project an image of a spot

along arrow **625** to be located at point A'. In this case, the projected spot intersects object **560** at location **628** so that the projected spot is displayed on object **560**. Subsequently, camera **530** may capture an image of object **560** including the projected spot. In the image, the projected spot and tip **565** of object **560** may be displaced from one another. Accordingly, the system may determine that object **560** is not touching surface **550** in response to detecting a projected spot on object **560** (as opposed to detecting the projected spot at tip **565**), for example.

FIG. **7** is a flow diagram of a process **700** to detect whether an object touches a surface, according to an embodiment. FIG. **8** is an image flow diagram of process **700**, according to one embodiment. At block **710**, a system may begin process **700**, which may be performed by a processor, such as **140** shown in FIG. **1**, for example. At block **720**, a surface map may be created to determine a profile of a surface **850** on which a virtual keyboard may be projected. An edge **855** of surface **850** is shown in image **802**, for example. Adjustments may be made to a projected image of a virtual keyboard, for example, based, at least in part, on such a profile. As mentioned above, such a profile of surface **850** may affect the way projected light is displayed on the surface. For example, a particular outline of a portion of a virtual keyboard projected by a projector onto surface **850** may be unchanged if the surface is flat. However, such a particular outline may include discontinuities corresponding to steps in a surface profile of the surface. In another example, such a particular outline may include correspondingly curved lines to compensate for a curved surface profile of the surface **850**. Accordingly, a processor, for example, may adjust or modify a projected image of a virtual keyboard, or other image, based, at least in part, on a profile of surface **850** that is to display the projected image.

At block **730**, a camera may be used to detect a presence of an object **860**. Such detection may be performed by comparing images **802** captured by the camera of surface **850** (which may include a projected virtual keyboard). A presence of an object may be determined if at least a portion of surface **850** (or a virtual keyboard) is obscured or blocked from view of the camera, for example. At diamond **740**, if an object is not detected, process **700** may return to block **730**, where the process continues to detect whether an object is present. If an object is detected, then process **700** may proceed to block **750**, where structured light or a light pattern may be generated and projected by a projector, for example. Also, subsequent to object detection, a location of a tip **865** of the object **860** may be determined in an image **804** captured by the camera. A light pattern may comprise a straight line **880**, which may be projected to be located at tip **865** of detected object **860**. Structured light may be generated according to a pre-generated surface map H that transfers an object tip point location captured from a camera into a corresponding projection location. Structured light or a light pattern (e.g., line **880**) may comprise IR light, invisible to a user, while a virtual keyboard, for example, displayed on surface **850** may comprise visible RGB light. Thus, a user need not see a line **880**, which is intended for use by a sensing device, such as **110**, and not a user. Accordingly, a camera in such a sensing device may be an RGB-IR camera.

Image **806** may comprise an image as "seen" by the projector of projecting line **880**. However, an image of tip **865** and line **880** captured by the camera may be different for a case where tip **865** touches surface **850** versus a case where tip **865** does not touch surface **850**. As mentioned above, a projector and a camera being separated by a distance may give rise to an image or pattern projected on a surface being dif-

ferent as viewed from the projector and the camera. Accordingly, image **808** comprises an image captured by the camera for the case where tip **865** is touching surface **850**. Here, line **880** may be continuous, crossing object **860** at tip **865**, for example. On the other hand, image **809** comprises an image captured by the camera for the case where tip **865** is not touching surface **850**. Here, line **880** may include an interruption or discontinuity **882**. Moreover, at least a portion **884** of line **880** may intersect object **860**. The distance between **884** and tip **865** may be used to determine the distance between the tip point and the touch surface **850**, for example.

Accordingly, returning to process **700**, at diamond **760** a determination may be made as to whether line **880** is broken, such as by including one or more discontinuities. In one implementation, a processor may evaluate an image, such as image **808** or **809**, to determine whether line **880** is broken, though claimed subject matter is not so limited. If line **880** is broken, then process **700** may proceed to block **770**, where a determination may be made that tip **865** does not touch surface **850**. On the other hand, if line **880** is not broken, then process **700** may proceed to block **780**, where a determination may be made that tip **865** touches surface **850**. In either case, process **700** may proceed to diamond **790**, where a determination may be made as to whether a surface map is to be re-created. Re-creating a surface map may be useful from time to time or subsequent to a particular event where surface **850** may change. Such a decision to re-create a surface map may be made by a user or an application executed by a processor, for example. Process **700** may return to block **720** to re-create a surface map, or return to block **730** to again detect a presence of an object. Of course, such details of process **700** are merely examples, and claimed subject matter is not so limited.

FIG. **9** is a flow diagram of a process **900** to detect whether an object touches a surface, according to another embodiment. In block **910**, a first image may be captured by a camera, such as camera **130**, or other light sensing device, for example. A first image may include an image of an object over a surface. At block **920**, light may be projected to create a light pattern on the surface. A pattern of such projected light may be based, at least in part, on the first image and a surface map of the surface, though claimed subject matter is not so limited. In one implementation, a projected light pattern may comprise a straight line on a flat surface.

At block **930**, a second image may be captured by the camera. The second image may include an image of the object and an image of the projected light pattern. At diamond **940**, a determination may be made as to whether the object touches the surface. In one implementation, the object may be determined to not be touching the surface if the light pattern in the second image includes one or more discontinuities, as explained above. On the other hand, the object may be determined to be touching the surface if the light pattern in the second image does not include a discontinuity. If the object is not touching the surface, then process **900** may proceed to block **950**, where a particular action, such as by a processor, for example, may be performed. For example, a processor may take no action and merely wait until the object touches the surface (which may include a display of a projected virtual keyboard, for example). If the object is touching the surface, then process **900** may proceed to block **960**, where a different particular action may be performed. For example, a processor may perform a particular action based, at least in part, on what portion (e.g., a location) of the surface (e.g., including a virtual keyboard) is touched. Of course, such details of process **900** are merely examples, and claimed subject matter is not so limited.

One skilled in the art will realize that a virtually unlimited number of variations to the above descriptions is possible, and that the examples and the accompanying figures are merely to illustrate one or more particular implementations.

While there has been illustrated and described what are presently considered to be example embodiments, it will be understood by those skilled in the art that various other modifications may be made, and equivalents may be substituted, without departing from claimed subject matter. Additionally, many modifications may be made to adapt a particular situation to the teachings of claimed subject matter without departing from the central concept described herein. Therefore, it is intended that claimed subject matter not be limited to the particular embodiments disclosed, but that such claimed subject matter may also include all embodiments falling within the scope of the appended claims, and equivalents thereof.

What is claimed is:

1. A method comprising:
   projecting, using a projector, an image portion on a surface, said image portion usable for surface mapping to enable transformation of location coordinates on said surface as seen by said projector to location coordinates on said surface as seen by a camera;
   capturing, using said camera, an image of said surface comprising said image portion;
   creating, using a processor, a surface map of said surface based at least in part on said captured image of said surface comprising said image portion;
   capturing, using said camera, a first image of an object proximate to said surface;
   determining, using said processor, a location of a tip of said object relative to said surface in said first image based, at least in part, on said surface map;
   projecting, using said projector, a light pattern to be located at said location of said tip and said surface, said light pattern being determined based, at least in part, on said first image and said surface map to transform said location of said tip captured from said camera to a corresponding projection location of said surface;
   capturing a second image of said light pattern superimposed on said object and/or said surface;
   determining whether said object touches said surface based, at least in part, on said second image.

2. The method of claim 1, wherein said determining whether said object touches said surface further comprises:
   determining that said object touches said surface in response to a determination that said light pattern in said second image does not include a discontinuity.

3. The method of claim 2, wherein said determining whether said object touches said surface further comprises:
   determining that said object does not touch said surface in response to a determination that said light pattern in said second image includes one or more discontinuities.

4. The method of claim 1, wherein said determining whether said object touches said surface further comprises:
   determining that said object does not touch said surface in response to a determination that said light pattern in said second image intercepts said object.

5. The method of claim 1, further comprising:
   determining a surface map mapping relationship between said surface and said camera and said projector.

6. The method of claim 1, wherein said light pattern comprises infrared (IR) light.

7. The method of claim 1, wherein said projected light pattern comprises a straight line on a flat surface.

8. The method of claim 1, further comprising:
   responding to a user action based, at least in part, on said determined location of said tip of said object and a determination of whether said tip of said object touches said surface.

9. The method of claim 1, wherein determining whether said object touches said surface comprises:
   determining that said object touches said surface in response to a determination that said light pattern is superimposed on said surface at said determined location; and
   determining that said object does not touch said surface in response to a determination that said light pattern is superimposed on said object at said determined location.

10. The method of claim 1, wherein determining said location of said tip of said object is based, at least in part, on a distance between said camera and said projector.

11. A touch sensing device comprising:
   a projector to project a projection image on a surface, said image to comprise an image portion usable for surface mapping to enable transformation of location coordinates on said surface as seen by said projector to location coordinates on said surface as seen by a camera;
   said camera to capture an image of said surface comprising said image portion;
   a processor to create a surface map of said surface based at least in part on said captured image of said surface comprising said image portion;
   wherein said camera is to capture a first image of an object proximate to said surface;
   wherein said processor is further to determine a location of a tip of said object relative to said surface in said first image based, at least in part, on said surface map;
   said projector to project a light pattern to said surface, wherein said light pattern is to be projected to said tip and said surface, said light pattern to be determined based, at least in part, on said first image and said surface map to transform said location of said tip captured from said camera to a corresponding projection location of said surface;
   said camera to capture an image of said light pattern; and
   said processor to determine whether said tip of said object touches said surface based, at least in part, on said image of said light pattern.

12. The device of claim 11, wherein said processor is to determine that said tip of said object does not touch said surface in response to a determination that said image of said light pattern includes one or more discontinuities, and wherein said processor is to determine that said tip of said object touches said surface in response to a determination that said image of said light pattern does not include a discontinuity.

13. The device of claim 11, wherein an optical axis of said camera is substantially non-orthogonal with respect to said surface.

14. The device of claim 11, wherein said light pattern comprises infrared (IR) light, visible light, or a combination thereof.

15. The device of claim 11, wherein said projector comprises a red-green-blue (RGB) projector.

16. The device of claim 11, wherein said projector comprises an RGB-1R projector.

17. The device of claim 11, wherein said camera comprises a visible-IR camera.

18. The device of claim 11, wherein said device is incorporated in a mobile device.

19. The device of claim **11**, wherein said surface map is based, at least in part, on a separation distance between said camera and said projector and a relative position to said surface.

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